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# A method and equipment for positioning when replacing anodes in an electrolysis cell

The present invention concerns a method for positioning when replacing anodes in an electrolysis cell, and equipment for carrying out this method.

Electrolysis cells of the Hall-Héroult type with prebaked anodes for the production of aluminium require regular replacement of used anodes with new ones during operation. Such prebaked anodes comprise a prebaked or calcined carbon block to which an anode suspender is attached via nipples that are fastened to the carbon block. The anode suspender and its nipples are of a metallic material. The combination of carbon block and anode suspender are usually called the anode, and this is fastened via the anode suspender to the superstructure of the electrolysis cell, more precisely to an anode beam that may run in the longitudinal direction of the cell. A standard cell design comprises two anode beams, and a certain number of anodes may be arranged side by side along each of the beams. Often each anode beam may have 8-10 anodes. The carbon material in the anodes is consumed during the electrolysis process and must be replaced before the metallic material in the nipples is revealed. This process takes approximately 28 days and, in an electrolysis hall with several tens of cells, there will be an extensive need for the removal of used anodes and the insertion of new ones. In this operation, it is important for the lower side of the new anode that is inserted to be positioned as correctly as possible in the position of the used anode in terms of height. This is because the interpolar distance (the distance between the anode and the cathode) is an important parameter in the cell.

Today this operation is increasingly performed using a traversing crane mounted on rails that runs along the rows of electrolysis cells and is usually positioned above them. The operation stated is one of the more labour-intensive and frequent operations during the operation of electrolysis cells, and the various players within the industry have developed improvements to simplify and rationalise this work while focusing on the safety and working environment of the operators. An established method of determining the insertion height of the new anode is to place it on a table beside the anode removed and to mark a common reference level on the anode suspender with chalk. A measuring stand is used as an auxiliary tool for this operation.

US patent no. 4,221,641 concerns a method and an arrangement for replacing electrodes in a reduction cell for the production of aluminium. The method involves the transport path of a used anode from the cell to a first level above the cell being registered so that the length of the electrode is measured, a new electrode being lowered, whereby the distance from a second level parallel to the first level is detected to measure the length of the new electrode, measurement of the distance between the levels stated and the new electrode being lowered further from the second level for a distance that is equal to the transport path of the used anode minus the distance between the two levels stated. To determine the level, this solution comprises an arm which is activated by the electrodes and which also has a detector to detect the arm's motion. The detector consists of a beam of light and a receiver, and the beam of light is broken by a screen mounted on the arm. The detector solution is of the optical/mechanical type with moving parts that easily can move out of position over time and/or require extensive maintenance/inspection to ensure the mobility and correct function of the components. This principle of measurement is based upon the use of an incremental counter in addition to limit switches, where the relative movement of the crane is counted.

The present invention represents a method and equipment for the replacement of anodes in an electrolysis plant that provide very precise positioning of the anodes and are more robust in the face of dust, wear and mechanical stress than prior art solutions. Moreover, the solution requires little inspection and has a good user interface for the operator who operates the crane.

These and further advantages may be achieved with the invention in accordance with the attached claims 1-10.

The present invention will be described in further detail in the following by means of figures and examples, where:

Figs. 1 a-b show elementary diagrams with vital parts of the measuring equipment, with and without an anode;

Fig. 2 shows an elementary diagram of how the measurements are performed.

As stated above, one intention of the present method is to achieve more precise insertion of anodes by means of more precise distance measurement using improved equipment involving distance measurement using a laser. This avoids random anode hoist measuring errors, and there is less possibility of incorrect operation thanks to the interlocking technology chosen. The measuring principle and the sequence used eliminate measuring errors in connection with the vertical deflection of the crane bridge and random play in the coarse structure.

Compared with manual measurement with a measuring stand and reference level, replacing anodes is less labour-intensive with this method – no operator is required on the floor for insertion and for positioning of the anode height, and the anode insertion height is more precise, which is important for the operation of the cell.

With reference to Figure 1a, the measuring equipment comprises a laser cell 3 installed inside a tight cabinet 4 with a vertical protection tube 5. The laser beam 7 shines through the tube towards a reflective tag 6 placed on the anode gripper 2. Under these circumstances, the laser cell will measure the precise distance. The tight cabinet, together with the protection tube and air overpressure that is supplied to the cabinet 4 via an air supply pipe 8, prevent fluoride dust and gas from reaching the cell's lens. This combination will produce precise measurement without random measuring errors. Cables for communication with the PLC run from the cabinet.

A lifting device, the anode hoist, is mounted on a rotation crab on the combination crane that is able to lift a burned-out anode out of an electrolysis cell and replace it with a new anode. The anode hoist is hydraulically controlled, i.e. the anode and anode suspender are lifted out of and lowered into the cell by means of hydraulic force.

The anode hoist is equipped with an anode gripper. This is a gripping device that is fastened to the anode hoist. It can grip the anode suspender 10 that is fastened to the anode 11 (see Fig. 1b). Conventionally, the anode suspender has a hole in its

upper part that can be gripped by a gripping device. Such gripping devices may comprise one ore more studs that can be entered into the hole in the suspender.

PLC means Programmable Logic Control. The PLC can control output signals (O) by means of input signals (I) and a logically constructed program. The PLC consists of several microprocessors. The PLC processor is located on the crane structure while several decentralised I/O racks are located on the mobile crabs and on the driver's cab. The decentralised I/O racks are linked to the PLC processor by means of high-speed data communication, which is very noise immune. This avoids having many signal cables, which may be vulnerable to noise and error signals.

In this connection, laser measuring equipment can measure the distance between the laser cell and a reflective tag. The precision of this combination is approximately 1 mm. The laser cell used in the example has RS-232 communication with the decentralised racks. The laser cell is expediently located inside a tight cabinet with overpressure attached to a flanged protection tube, for example of diameter 50 mm and length approximately 2.5 m. The laser beam is designed so that it shines from the cabinet through the tube and down towards the reflective tag on the anode gripper.

RS-232 (ASCII characters – port to port) communication is a data communication method that precisely transfers signals from the laser cell to the PLC.

A PanelView (not shown) is a screen-based visualisation system that communicates with the PLC via the same communication method as for decentralised I/O racks. This visualisation system can read off all values saved as described below so that the crane driver in the cabine can read the values.

A light panel (not shown) comprises a column of light with 5 lights of different colours. This light panel has 2 function modes. Mode 1 is used when removing the anode and indicates the measuring sequences step by step. Mode 2 is positioning indication when inserting the anode. This indicates when the anode is too high, too low or in the correct position. This is based on an algorithm that is programmed in the PLC.

1) PLC Interlocking (PLC interlocking in the PLC-program)
The sequence is interlocked so that mechanical play is always eliminated. This is done by the operator having to use the joystick for the anode hoist UP STAGE 1 for a minimum of 2 seconds and to use the REMEMBER MEASURED VALUE switch at the same time before the anode gripper position is saved in the PLC.
When the joystick for the anode hoist is in the position UP STAGE 1, the hydraulic aggregate ensures, with the appropriate valves, that the anode hoist has approximately 60-70% lifting force in relation to the weight of a burned-out anode.

2) Integrated PLC Solution
The PLC installation results in the signal transfer between the laser cell and the PLC being very noise immune, the signal transfer being reliable and random error measurements not being produced.

3) Visualisation
Simple visualisation shows the sequence and produces reliable positioning of the new anode.

The crane in the example is controlled by the PLC with intelligent decentralised I/O racks. The distance laser measuring equipment communicates with the decentralised I/O racks. The laser cell and one decentralised rack must be positioned on the anode hoist as the laser cell transfers measured values to the PLC processor via an intelligent decentralised I/O rack. It is important for the transfer of values between the laser cell and the PLC to be as noise immune as possible in relation to electromagnetic and electrostatic beams and not to be affected by temperature fluctuations in order to avoid error signals. This is achieved with the PLC structure chosen.

The laser measuring equipment with the laser cell is, as stated above, located inside a dust-tight cabinet 4 (the electrotechnical designation is IP 56) on the rotating anode hoist crab. The cabinet has a flanged tube 5 of diameter 50 mm and length approximately 2.5 m mounted on it, which extends down towards the reflective tag 6.

The reflective tag is fastened to the anode gripper 2. The laser measuring equipment measures the distance between a fixed point in this tight cabinet (the installation location) on the anode hoist through the tube and down towards the reflective tag on the anode gripper. The tight cabinet is provided with overpressure and a long tube as stated so that the powerful upward air flows (hot air with a lot of gas containing fluorine and dust in connection with anode replacement) do not reach the lens of the laser cell. This is an important detail in the prevention of error measurements. The laser measuring principle described is a central part of the present invention as it is not subject to mechanical wear and does not require maintenance.

A PanelView 550 visualisation panel is installed inside the crane cab so that all measurements and stages in the sequence can be read off. This is controlled by the PLC.

A function light panel is installed in front of the operator with 5 indicator lamps. This function display has 2 modes. This is made for the operator to let him monitor the functions in connection with the insertion of anodes, in particular the mounting height for the new anode (for more information, see the functional description).

The operator's controls comprise a joystick on the left side, which has 3 stages for upward movement of the anode gripper.
UP STAGE 1 exerts a lifting force on the anode gripper of approximately 60-70% of the weight of the burned-out anode and has a relatively low lifting speed. This force setting is used when the anode gripper height needs to be measured using the laser equipment.
UP STAGE 2 exerts a lifting force on the anode gripper of approximately 300% of the weight of the burned-out anode (breakaway force when removing an anode) and has the same speed as UP STAGE 1.
UP STAGE 3 exerts a lifting force on the anode gripper of approximately 200% of the weight of the burned-out anode and has a high speed for rapid anode handling.
On the same joystick as stated above, there is a press-button switch at the front. This is used to operate REMEMBER ANODE GRIPPER POSITION.

<u>Functional Description, see Figure 2</u>

All the functions described are carried out by the operator in the crane cab. The operator first sets the offset value on the PanelView, i.e. how much higher the new anode is to be inserted in relation to the burned-out anode (the typical setting is 20 mm). The operator guides the crane so that he grips the anode suspender (the anode) with the anode gripper. He then lifts the burned-out anode by operating the anode hoist UP STAGE 1 with the joystick (see Figure 2a). This involves the anode hoist lifting with a preset force that is approximately 60-70% of the anode weight (constant force). This results in the elimination of play. While the lifting is taking place, the operator presses the REMEMBER POSITION switch on the joystick. The anode gripper position is saved in the PLC if UP STAGE 1 lifting has been active continuously for 2 seconds. If the operator uses UP STAGE 2, the anode gripper position will not be saved in the PLC. This is an important interlocking function in the PLC to eliminate play and to ensure that the crane is deflected in approximately the same way for all measurements. When this has been done in accordance with the method, the PLC will acknowledge this with a yellow light on the light panel. This means that measurement A has been completed. The anode clip is loosened and the burned-out anode is removed from the cell.

The bumed-out anode is placed down on the reference level (checker plate), see Figure 2b. The anode is lifted up by using anode hoist UP STAGE 1, i.e. the anode hoist will again lift with approximately 60-70% of the anode weight. The burned-out anode will not be lifted from the reference level, but the crane structure is extended in the same way as when lifting the anode out of the cell. This results in the play in the crane being eliminated. While the lifting is taking place, the operator presses the REMEMBER POSITION switch on the joystick. The position is saved in the PLC if the UP STAGE 1 lifting was active for 2 seconds. When this has been done correctly, the PLC will acknowledge this with a green light on the light panel. This means that measurement B has been completed.

The old anode is then placed in a waste bin. The new anode is fastened to the anode gripper. This is then placed on the same reference level as for the burned-out anode, see Figure 2c. The anode is lifted up by using UP STAGE 1, i.e. the anode hoist will again lift with approximately 60-70% of the anode weight. While the lifting is taking

place, the operator presses the REMEMBER POSITION switch on the joystick. The position is saved in the PLC if the UP STAGE 1 lifting was active for 2 seconds. When this has been done correctly, the PLC will acknowledge this with a red light on the light panel. This means that measurement C has been completed. All the measurements have now been completed.

The PLC calculates the insertion height of the new anode using this formula – see Figure 2d:

D=A-B+C-X

D is the desired position of the new anode.

A is the position of the burned-out anode in the cell.

B is the position of the burned-out anode on the reference level.

C is the position of the new anode on the same reference level.

X is the additional height of the new anode in the cell in relation to the burned-out anode.

The new anode is inserted in the cell at anode position = D (+/- tolerance, typically +/- 3 mm - the tolerance can be adjusted from the operator panel).

The indicator panel then switches to Mode 2 for indication. The operator inserts the anode in the cell in accordance with the light indication in Mode 2, i.e. if the yellow lights light up (1 or 2 yellow lights), the anode is too high, and if the red lights light up (1 or 2 red lights), the anode is too low. The anode has the correct height position if the green light lights up, i.e. the anode is in position D +/- 3 mm. When the anode is positioned in the cell and the green light lights up, the anode is fixed with the anode clamp. The sequence has been completed, and the equipment can be used to replace an anode in another cell.

Additional insertion height for a new anode is important to avoid anode deformation. The additional height means that the anode does not draw "full power", and it is allowed to heat up gradually before full current flows through it.